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Experiments to Determine the Effects of Different Flash Suppressor Designs on Accuracy of an F89 Light Machine Gun

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DSTO

DEPARTMENT OF DEFENCE
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Aeronautical and Maritime Research Laboratory

ABSTRACT

General Document

Tests were performed to determine the accuracy of an Australian F89 light machine gun having barrels fitted with or without flash suppressors. The results of these experiments are presented in this report. It was observed that the addition of a flash suppressor from a MAG 58 machine gun can reduce the size of mean radius dispersion by as much as 41% over an original Minimi flash suppressor and 35% over none being fitted. It appears that when using standard taper-ended Minimi barrels 19% of this improvement can be attributed directly to the mass of the MAG 58 flash suppressor but that this mass has no apparent effect on accuracy when using heavier F89 barrels.

It was concluded that gasdynamic effects due to flash suppressor design may have a significant role in weapon accuracy and merit further study.

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Experiments to Determine the Effects of Different Flash Suppressor Designs on Accuracy of an F89 Light Machine Gun

1. Introduction

In 1989 the Engineering Development Establishment conducted, on behalf of the Small Arms Replacement Project (SARP), an evaluation of the FN Minimi (now referred to in the Australian inventory as the F89) light machine gun to ascertain its level of acceptance into Australian service. In an isolated test in March 1989 it was found that significant reductions in the dispersion size of 5-round bursts were achieved when the original Minimi flash suppressor was replaced with a flash suppressor from either the F88 rifle or from a MAG 58 general purpose machine gun [1]. It was not known whether the improvement in burst dispersion was due to the increase in mass thereby reducing vibration to the barrel assembly, an increase in the gas dynamic efficiency associated with the flash suppressor vent design, or a combination of both.

Army subsequently tasked MRL to conduct experiments on an F89 light machine gun to determine target dispersion when fitted with either FN Belgian Minimi barrels or Australian barrels built at the ADI facility at Lithgow. Tests were designed to determine the effect of different flash suppressors (FS) on accuracy, and this included the standard pattern Minimi FS, a MAG 58 FS, or no FS at all. Photographs showing these two FS designs are given in figures 1 and 2.

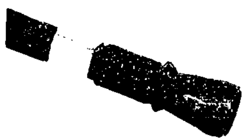

Figure 1: Standard Minimi flash suppressor

Figure 2: MAG 58 flash suppressor

2. Experimental

A special test fixture was constructed to rigidly support the F89 weapon such that any movement detected at the muzzle could only be associated with variations in barrel position and not of the whole gun (figure 3).

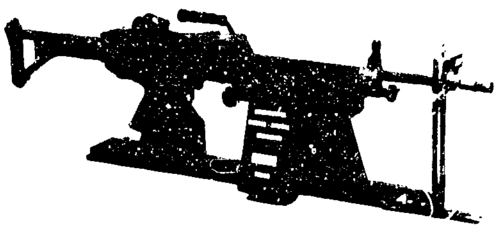

Figure 3: F89 gun fixture

When work commenced on the project, it was decided that much information could be gained if, for each round fired from the weapon, a correlation could be drawn between the movement of the gun muzzle and the position of the shot's impact at the target. To determine this, an optical proximity switch was constructed which enabled muzzle deflection to be measured in both the vertical and horizontal planes (figure 4). A complete description of the operating principles of the proximity device can be found in Appendix 1. The outputs from

the proximity switches were fed into a 2-channel digital transient recorder (Le Croy type 9410). A hardcopy of the barrel motion traces could be obtained from a graphics plotter connected to the recorder. A probe which detects the ionised propelling gases was used to determine the precise moment the projectile left the barrel.

Figure 4: Barrel muzzle showing optical proximity switches

Initial experiments designed to test the operation of the proximity switches were conducted using an ex SARP trialled Minimi light machine gun (receiver no FN 008866) held at EOD. As this gun was in a very worn state a weapon more suited to the task (receiver no. FN 030911) along with a new Minimi barrel (part no. 9348420), a worn but supposedly still usable F89 barrel (part no. AM 900033-2 produced at ADI Lithgow) and several hundred rounds of Australian made 5.56 mm x 45 mm F1 ball ammunition (dated AFF 5-12-88) were obtained from EDE.

All tests were performed at the 60 m indoor gun firing range facility located at EOD Salisbury. The indoor facility, despite being somewhat limited in range, did have the advantage of providing an environment where the flightpath of the projectiles was not affected by cross winds. The location and identification of rounds as they impacted the target area was performed using a grid pattern and a video camera. The grid pattern consisted of a series of square segments each 100 mm wide by 100 mm high. Each target was 600 mm in width by 800 mm in height. A video camera and light source were positioned in such a way that the target could be viewed with minimal distortion but out of the line of fire. As an

additional precaution the video camera was protected by an aluminium box fitted with a polycarbonate viewing window to prevent damage from wood and metal splinters emanating from the projectile catcher. The camera was connected to a VHS video recorder (VCR) and monitor. The VCR was set to record during a firing. On single-frame playback the location and order of impacts could be simply visualised, and the approximate positions noted. Measurements were later taken with a ruler and the coordinates of each shot in a series thus determined. The target was repaired with paper adhesive tape before the next firing.

The tabling of bullet dispersion results emulated the procedure used at EDE [1]. The impact position of each 5-round group was noted and the mean coordinate position calculated (herein known as its mean point of impact or MPI). The maximum spread in both horizontal (X) and vertical (Y) planes and the extreme spread (the distance between the two furthermost impacts) were also determined and standard deviations (SD) calculated. The spread provides a guide to the overall shape of the distribution. More helpful however to the measurement of dispersion is the calculation of mean radius (MR) which is defined as the average radial distance of the impacts relative to the MPI in a given burst. The standard deviation is a guide to the consistency with which the MR is maintained. Finally the average, standard deviation, minimum and maximum figures would be calculated for each firing serial (repeated bursts of a given test configuration).

The gun support rig was adjusted in such a manner that when the Minimi barrel was used without any flash suppressor devices fitted, the mean distribution of a 5-round burst would be about the centre of the grid pattern.

Early experiments were performed by firing belts containing 5-rounds of linked ammunition. In subsequent testing an M16-type magazine loaded with 5-rounds was used as it simplified the firing procedure and appeared to have no adverse effects on muzzle motion or accuracy. All testing was performed with the barrel gas port configured in the "normal", ie maximum, vented position

3. Results

3.1 F89 barrel

Tests were performed with the EDE weapon (receiver no F 030911) and the worn Australian made F89 barrel (part no AM 900033-2). This barrel has some obvious visual differences from its Belgian (Minimi) counterpart. The F89 barrel is parallel sided throughout its length whereas the FN barrel tapers towards the muzzle from about 2/3rds up the barrel length The local variant is threaded (right-hand thread) to accept the direct fitting of a MAG 58 flash suppressor, whereas the FN barrel has a left-hand thread with a smaller diameter than the F89's thread as it is designed to accept the conically shaped Minimi flash suppressor The front sights also differ and this would presumably have an effect on the barrel frequency characteristics. Figure 5 shows the different barrel and flash suppressor combinations

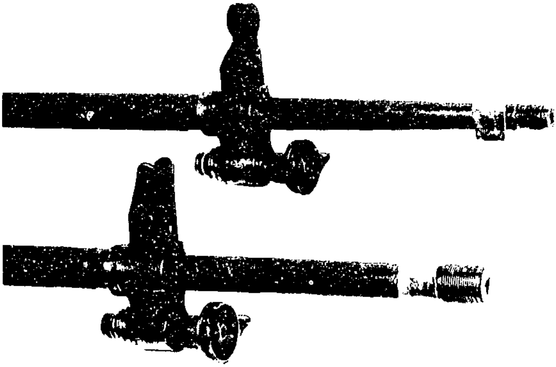

Figure 5: Minimi and F89 barrels

When fired this combination produced the target impact distribution as shown in Table 1:

TABLE 1. Target dispersion at 60 metres using a worn ADI-L barrel (5-round bursts)

ARRANGEMENT	SPREAD (mm)					DISPERSION (mm)	
NO FLASH SUPPRESSOR - 4 BURSTS	X Horizontal Plane	Y Vertical Plane	Extreme	SDx Standard Deviation (X)	SDy Standard Deviation (Y)	MR Mean Radius	MRSD Mean Radius Standard Deviation
Average	391	478	568	162	180	181	126
Std. Deviation	57	86	152	25	37	12	40
Minimum	350	380	412	136	135	171	91
Maximum	475	585	754	192	212	196	180
MINIMI FLASH SUPPRESSOR - 4 BURSTS							
Average	301	579	579	124	230	201	130
Std. Deviation	122	107	107	38	50	49	25
Minimum	200	435	442	93	158	142	93
Maximum	475	690	767	175	273	261	147
MAG 58 FLASH SUPPRESSOR - 4 BURSTS							
Average	413	473	601	175	189	226	89
Std. Deviation	114	241	145	62	102	77	16
Minimum	255	135	483	101	50	168	78
Maximum	510	705	811	247	296	337	112

Hit dispersion and spread levels at the target appeared to be abnormally large. It was also evident that this barrel always produced a large spread at the target irrespective of which FS was fitted. No correlation was evident between the individual impact points and the position of the muzzle at shot exit.

Microflash photography was used in an attempt to determine muzzle gas flow behaviour with different FS fitted as well as projectile behaviour. In microflash operation, a polaroid camera is situated in a darkened range and operated in open-shutter mode with a high speed electronic flash for exposure. Figure 6 shows significant projectile yaw as it leaves this barrel.

Figure 6: Microflash photograph of a projectile leaving the muzzle of a worn F89 barrel (note large yaw angle)

A narrow sharp spike is visible on the vertical and horizontal measurement of barrel deflection just before the projectile leaves the barrel (see figure 7). This feature is less visible on records where a flash suppressor was fitted and almost negligible whenever the Minimi barrel was tested. Close inspection of the F89 barrel revealed that the bore in the first 50mm of rifling at the chamber end was severely eroded and would have been a major contributor to the dispersion noted

above. It is also believed that the spike seen on the muzzle motion records was caused by infra-red interference resulting from excessive blow-by in the worn barrel. It was therefore decided to abandon futher testing with this barrel and resume testing with the Minimi barrel until a new F89 barrel could be obtained.

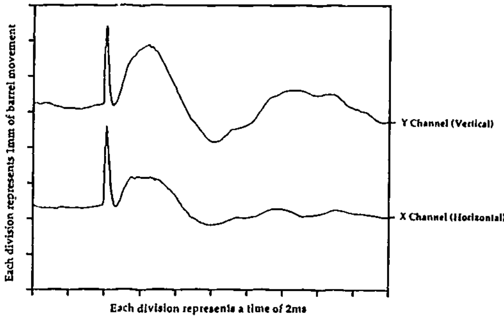

Figure 7: Spikes visible on both vertical and horizontal muzzle traces for a worn F89 barrel. The trace shows the effect of a single shot for the case of no FS

3.2 *Minimi barrel*

A new Minimi barrel was fitted to the test weapon and experiments were performed with a number of different flash suppressor combinations. Table 2 provides a summary of the dispersion results. It was necessary to use a specially designed adaptor which enabled the relatively large diameter right hand threaded MAG FS to be attached to the left hand thread fitting of the Minimi barrel.

TABLE 2. Target dispersion at 60 m using a new Minimi barrel (5-round bursts)

ARRANGEMENT	SPREAD (mm)					DISPERSION (mm)	
NO FLASH SUPPRESSOR - 6 BURSTS	X Horizontal Plane	Y Vertical Plane	Extreme	SDx Standard Deviation (X)	SDy Standard Deviation (Y)	MR Mean Radius	MRSD Mean Radius Standard Deviation
Average	138	124	185	58	51	67	30
Std. Deviation	78	52	69	34	18	22	15
Minimum	65	35	139	29	17	48	15
Maximum	280	175	320	120	70	107	59
MINIMI FLASH SUPPRESSOR - 8 BURSTS							
Average	126	161	200	53	65	71	34
Std. Deviation	34	77	57	15	30	1	12
Minimum	90	60	101	34	23	33	22
Maximum	180	230	271	76	103	93	54
MINIMI F. S. & MATCH AMMO - 3 BURSTS							
Average	147	148	201	62	57	73	33
Std. Deviation	63	74	34	28	26	22	2
Minimum	75	65	179	31	28	60	39
Maximum	195	205	240	85	77	98	34
MAG 58 FLASH SUPPRESSOR & ADAPTOR - 17 BURSTS							
Average	94	81	111	38	32	41	20
Std. Deviation	50	35	47	18	15	17	11
Minimum	40	25	56	15	11	23	6
Maximum	205	170	224	68	73	87	41
EDE MINIMI F.S. & ADAPTOR - 8 BURSTS							
Average	154	146	208	63	60	75	35
Std. Deviation	33	88	63	16	35	24	11
Minimum	110	75	141	45	29	47	23
Maximum	200	320	335	91	129	118	59
ADAPTOR ONLY - 9 BURSTS							
Average	138	147	186	55	62	73	28
Std. Deviation	62	56	49	24	26	20	15
Minimum	30	75	78	13	32	30	9
Maximum	205	245	249	82	104	100	50

As can be seen from the above results the Minimi barrel, even without a flash suppressor fitted, decreased the size of the target dispersion dramatically c.f. the worn F89 barrel. A careful examination of the coordinate position of each target impact with the direction of the weapon's muzzle at the moment of shot release indicated that there was still no obvious correlation between them. It was initially believed that some non-uniformity in the design of standard F1 projectiles may have had a bearing on this outcome and thus a handful of these projectiles were replaced with projectiles of match-grade quality. However, as can also be seen from the above table, these projectiles had little effect on dispersion nor, as it happened, on the muzzle position/target impact relationship. Therefore, the use of match-grade ammunition was not pursued. The results above did prove however that the fitting of a MAG FS onto the end of this Minimi barrel

significantly reduced the size of the target impact dispersion by producing an MR 41% smaller than that obtained when using the original Minimi FS.

The recordings of muzzle motion generally exhibited a high frequency component of about 15 kHz which was less visible in those signals obtained whenever the MAG FS was fitted. There also appears a possible reduction in the frequency of oscillations from about 120 Hz to about 75 Hz when fitting the MAG FS. Figures 8 to 10 show typical muzzle XY waveforms for the first few shots of a five-round burst when using a Minimi barrel without its FS, with its original Minimi FS and with a MAG FS respectively. Another observation is that the barrel appears to have virtually come to rest before the next round is fired. This means that the deflection characteristics of the first round are essentially the same as with subsequent rounds.

Most tests involving the use of the muzzle proximity detectors concentrated the collection of data in the region up to 1 ms either side of shot exit from the barrel. The remainder of the vibration cycle was presumed not to have any effect on the positioning of the round. This process also enabled all five shots in a group to be measured in the one recording. The projectile appears to leave the barrel before the first large harmonic swing occurs (see figures 11 & 12). The only exception to this appears to be when attaching the MAG FS to the barrel. Here shot exit appears to occur halfway up the first swing (see figure 13). It does appear that the shot exit's change in position is due to the large length of the MAG FS which may have acted as a shield preventing the ionised gas from reaching the shot exit probe until after the projectile has left the end of the FS and not the end of the barrel.

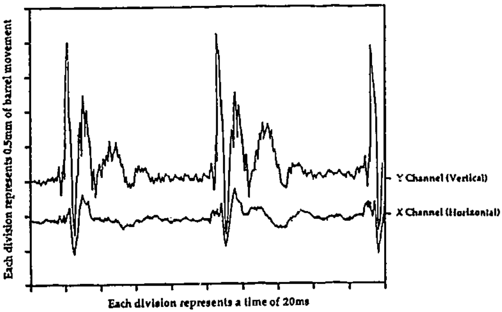

Figure 8: Muzzle displacement curves - Minimi barrel and no flash suppressor

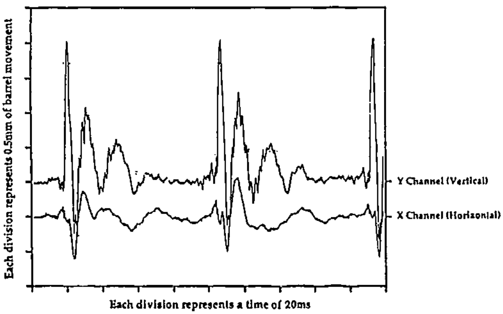

Figure 9: Muzzle displacement curves - Minimi barrel and Minimi flash suppressor

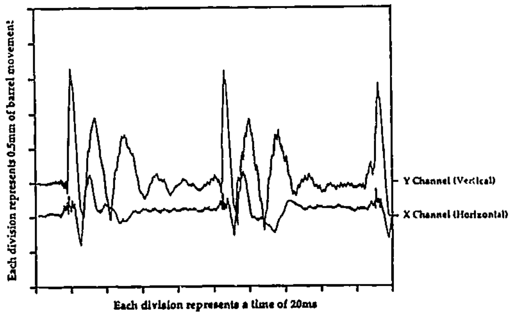

Figure 10: Muzzle displacement curves - Minimi barrel and MAG flash suppressor

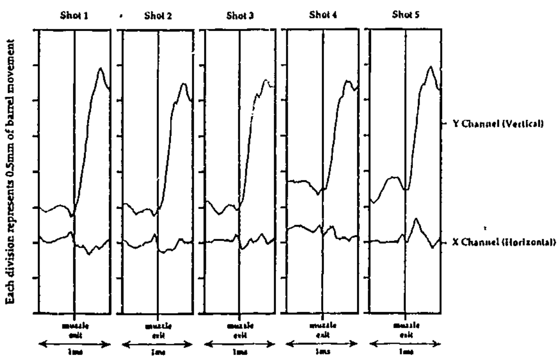

Figure 11: Typical XY muzzle proximity trace of a Minimi barrel (no FS fitted) and a 5-round burst

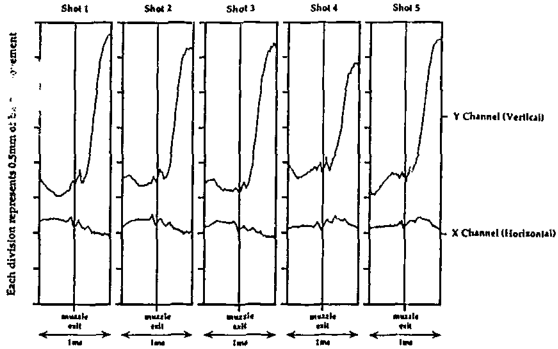

Figure 12: Typical XY muzzle proximity trace of a Minimi barrel (Minimi FS fitted) and a 5-round burst

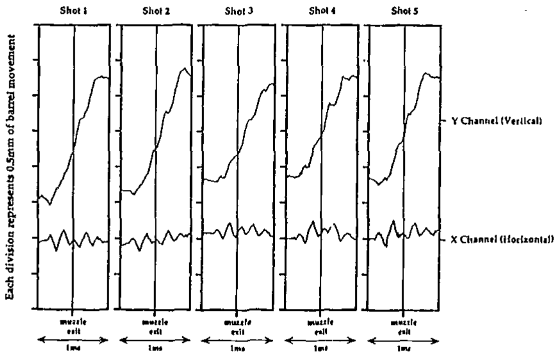

Figure 13: Typical XY muzzle proximity trace of a Minimi barrel (MAG FS fitted) and a 5-round burst

It was also observed that the Minimi FS does not reduce dispersion any more than if no FS were used and that the addition of any form of FS shifts the MPI down and to the right of the original target impact point. This latter effect appears to be the result of mounting asymmetry. To validate this observation disk-shaped screw-on weights were attached to the muzzle end of the barrel. One of these was identical in mass to the MAG 58 FS (138g) while the other was heavier at 322g. Used in isolation, each mass provides a small improvement in dispersion (18-19%) c.f. the Minimi FS (see Table 3). The shift in MPI down and to the right still occurs.

TABLE 3. Target dispersion using the new Minimi barrel and various masses attached to the muzzle end of the barrel (5-round bursts)

ARRANGEMENT	SPREAD (mm)					DISPERSION (mm)	
322G WEIGHT & ADAPTOR	X Horizontal Plane	Y Vertical Plane	Extreme	SDx Standard Deviation (X)	SDy Standard Deviation (Y)	MR Mean Radius	MRSD Mean Radius Standard Deviation
Average	109	128	152	46	50	58	24
Std. Deviation	40	24	21	15	7	8	4
Minimum	55	100	121	22	41	47	19
Maximum	155	165	181	66	60	69	28
138G WEIGHT & ADAPTOR							
Average	115	129	162	43	54	57	30
Std. Deviation	59	27	42	21	12	8	14
Minimum	45	95	126	17	37	48	18
Maximum	200	170	209	71	37	48	18

An attempt was made to characterise the full XY motion of the muzzle over time in order to establish whether a specific trend occurred for the various combinations used. Figures 14 and 15 show the barrel motion trends for an F89 barrel minus its flash suppressor and fitted with a MAG FS. It should be stressed that as the round appears to have left the barrel before completion of the first upwards swing that subsequent motion would have no further effect on the accuracy of the round.

It was observed that neither the dispersion nor the MPI altered when the MAG 58 FS was rotated by a few degrees (so that a bar was positioned where formerly was a slot) or as much as 90° to test for assymmetry.

An interesting observation was that if the barrel's support latch was securely held in place while the weapon was fired (no FS fitted), the dispersion would also be reduced (see Table 4). This observation however was not repeated when using the new Australian made F88 barrel.

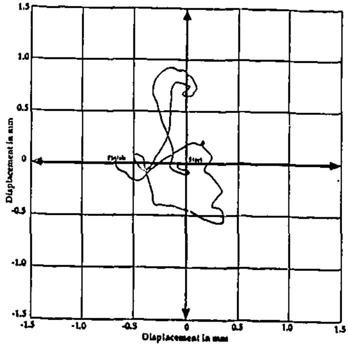

Figure 14: Graph showing a complete and typical XY muzzle displacement oscillation of a Minimi barrel (no FS - single shot)

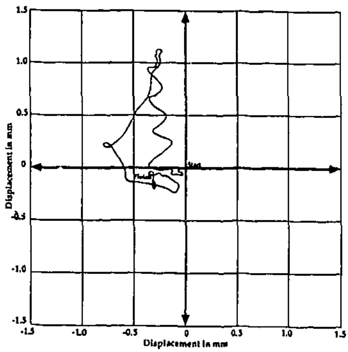

Figure 15: Graph showing a complete and typical XY muzzle displacement oscillation of a Minimi barrel (MAG FS - single shot)

TABLE 4. Dispersion characteristics using various weight/flash suppressor combinations (5-round bursts)

ARRANGEMENT	SPREAD (mm)					DISPERSION (mm)	
MAG 58 F.S. & 322G WEIGHT & ADAPTOR	X Horizontal Plane	Y Vertical Plane	Extreme	SDx Standard Deviation (X)	SDy Standard Deviation (Y)	MR Mean Radius	MRSD Mean Radius Standard Deviation
Single Burst	70	80	85	26	33	35	17
MAG 58 F.S. & 138G WEIGHT & ADAPTOR							
Single Burst	65	85	101	26	33	33	18
EDE MINIMI F.S. & 322G WEIGHT & ADAPTOR							
Single Burst	120	100	123	46	38	49	26
NO F.S. BUT REAR BARREL LATCH HELD							
Single Burst	140	60	147	56	27	50	27
MAG 58 F.S UNSCREWED 6MM OUT - 4 BURSTS							
Average	68	59	81	28	24	30	14
Std. Deviation	15	27	20	7	10	8	8
Minimum	55	25	56	24	11	23	7
Maximum	85	90	103	38	34	40	25

Adding extra mass to the MAG 58 FS appeared at first glance to reduce dispersion further but as can be seen from the above table this was due more to the FS being repositioned 6mm further out in order to accommodate the additional mass.

Firing the F89 with the muzzle clamped firmly in position also reduced the size of the dispersion pattern but more so when fired in conjunction with the MAG 58 FS than with the Minimi styled FS (see Table 5).

TABLE 5. Dispersion characteristics with muzzle fixed in position

ARRANGEMENT	SPREAD (mm)					DISPERSION (mm)	
EDE MINIMI F.S. & ADAPTOR - 6 BURSTS	X Horizontal Plane	Y Vertical Plane	Extreme	SDx Standard Deviation (X)	SDy Standard Deviation (Y)	MR Mean Radius	MRSD Mean Radius Standard Deviation
Average	105	97	124	40	40	47	21
Std. Deviation	52	37	49	19	17	21	8
Minimum	55	45	80	20	17	28	12
Maximum	200	145	209	73	67	84	32
MAG 58 F.S. & ADAPTOR - 6 BURSTS							
Average	88	60	97	33	24	34	17
Std. Deviation	19	22	21	7	9	6	6
Minimum	50	35	58	21	14	26	7
Maximum	105	90	114	40	36	41	25

Fixing the muzzle in such a manner so that the barrel corresponded to either of the maximum vertical extremes merely shifted the MPI correspondingly up or down but had no effect on the size or shape of the dispersion patterns.

3.3 *Thick walled proof type barrel*

An experiment was performed to determine the effect on bullet impact distribution of a thick walled single shot proof type barrel fitted without a flash suppressor or with a MAG 58 FS. The barrel used had a 1 in 7 inch twist rifling to accept the SS109 type of 5.56mm calibre ammunition. The barrel length was shortened so that it conformed with the F89 barrel. Firings were performed in groups of 5 in such a manner that the time between shots was less than 30 seconds. Table 6 summarises the results of these tests. The thick wall of this barrel would no doubt have contributed to the small size of the dispersion pattern (being essentially infinitely stiff). It would appear that in this instance the MAG FS did not do anything to reduce an already small dispersion size.

TABLE 6. Bullet dispersion sizes for a thick walled barrel with and without a flash suppressor

ARRANGEMENT	SPREAD (mm)					DISPERSION (mm)	
HEAVY WALLED BARREL & MAG 58 FS - 4 GROUPS	X Horizontal Plane	Y Vertical Plane	Extreme	SDx Standard Deviation (X)	SDy Standard Deviation (Y)	MR Mean Radius	MRSD Mean Radius Standard Deviation
Average	42	29	44	17	12	18	7
Std. Deviation	8	8	8	3	4	3	3
Minimum	31	19	34	12	9	14	4
Maximum	48	38	52	20	17	21	10
HEAVY WALLED BARREL & NO FS - 4 GROUPS							
Average	32	41	51	13	16	17	10
Std. Deviation	12	12	12	5	6	3	3
Minimum	17	27	34	6	11	14	5
Maximum	45	57	60	19	24	20	12

3.4 *New F89 barrel*

Many tests were repeated as for the Minimi barrel but with a new F89 barrel purchased from ADI - Lithgow. As the barrel was received without its gas block and handle these were subsequently removed from the worn F89 barrel and fitted to the new barrel in accordance to instructions from the manufacturer. This included setting the gas regulation to have the weapon firing at the correct rate.

Tests included firing the weapon/F89 barrel without a FS, with a MAG 58 FS, with a disk shaped weight (138g) and finally with a weight having the same overall mass distribution of the MAG FS but without the slots (referred to here as the MAG facsimile - see figure 16). Table 7 summarises the results of these tests.

TABLE 7. Dispersion characteristics of a new F89 barrel with various flash suppressor combinations

ARRANGEMENT	SPREAD (mm)					DISPERSION (mm)	
NO FLASH SUPPRESSOR - 8 BURSTS	X Horizontal Plane	Y Vertical Plane	Extreme	SDx Standard Deviation (X)	SDy Standard Deviation (Y)	MR Mean Radius	MRSD Mean Radius Standard Deviation
Average	129	114	153	50	46	57	26
Std. Deviation	62	38	49	24	14	18	12
Minimum	50	40	76	22	17	29	11
Maximum	220	155	241	87	60	84	49
MAG 58 FLASH SUPPRESSOR - 7 BURSTS							
Average	71	76	91	30	31	37	14
Std. Deviation	35	22	34	13	9	12	8
Minimum	30	55	55	15	24	24	7
Maximum	140	110	157	57	45	59	29
138G WEIGHT - 3 BURSTS							
Average	108	152	164	44	61	64	26
Std. Deviation	25	20	26	12	7	5	1
Minimum	85	140	142	32	53	59	25
Maximum	135	175	192	55	67	69	27
MAG FACSIMILE - 4 BURSTS							
Average	118	134	166	48	52	58	29
Std. Deviation	28	63	61	14	23	21	9
Minimum	80	70	103	30	28	41	20
Maximum	145	215	242	61	60	81	41

These results confirm the improvement to dispersion when using a MAG 58 FS. The improvements to dispersion found when the Minimi barrel was fitted with any of the muzzle masses was not repeated when using the F89 barrel. Holding the barrel support latch while firing with the Minimi barrel attached rendered an improvement whereas the same did not occur when the F89 barrel was attached (it was noted that this barrel seemed to be more firmly held in place than the Minimi barrel was). It would appear that the parallel sides of the F89 barrel possibly makes this barrel more rigid than the Minimi barrel and that no further improvements can be made as a result of any additional clamping.

Unscrewing the MAG FS outwards seems to reduce the MR even further, suggesting a change to the gas flow to be the cause. In order to validate this latter observation an additional test was performed with EOD's own Minimi fitted with the new F89 barrel (the EDE weapon was no longer available at the time of this test). The weapon was fired with a MAG FS fitted in the fully home position and the resultant dispersion compared to that which was obtained when the FS was unscrewed several mm forward of the home position. Table 8 summarises these results.

TABLE 8. Results of firings with the EOD Minimi and fitted with the new F39 barrel and MAG flash suppressor.

ARRANGEMENT	SPREAD (mm)					DISPERSION (mm)	
	X Horizontal Plane	Y Vertical Plane	Extreme	SDx Standard Deviation (X)	SDy Standard Deviation (Y)	MR Mean Radius	MRSD Mean Radius Standard Deviation
MAG 58 F.S. - 4 BURSTS							
Average	102	131	141	43	55	59	21
Std. Deviation	39	27	28	16	9	16	8
Minimum	52	115	115	21	47	40	15
Maximum	146	172	182	60	68	78	31
MAG 58 F.S. UNSCREWED 10MM - 4 BURSTS							
Average	93	126	144	34	50	49	28
Std. Deviation	38	49	34	14	16	9	13
Minimum	46	69	107	18	31	40	15
Maximum	139	189	190	52	70	60	44

It can be seen from the above results that the EOD weapon, as a result of its worn state, produces a somewhat larger MR than the EDE weapon under identical conditions (59 cf. 37).

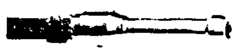

Figure 16: Photograph of the MAG FS facsimile

4. Discussion

The following observations can be made from the complete results described above.

a. The MAG FS reduces the MR by approximately 41% over the standard Minimi barrel fitted with its original FS, and by 35% over a bare F89 barrel.

b. Using either the standard Minimi FS or the EDE manufactured Minimi FS together with its adaptor do not seem to provide any obvious reduction in the size of the dispersion pattern.

c. Adding a mass or FS will alter the MPI, but not necessarily the size of the dispersion pattern.

d. A 138g disk-shaped weight, hung on the muzzle end of a tapered Minimi barrel, appears to reduce the impact dispersion by as much as 19% c.f. a barrel fitted with its original FS.

e. Adding any additional weight beyond 138g will not further reduce the dispersion when fitted to the muzzle end of the Minimi barrel.

f. Any weight in isolation, when fitted to the muzzle end of an F89 barrel, will not reduce the MR.

g. From the barrel movement data at the muzzle, the projectile appears to leave the barrel before the first sizeable harmonic.

h. During a burst the barrel appears to have essentially come to rest before the next round is fired.

i. There is no apparent correlation between muzzle position and individual impact at the target.

j. A reduction in the frequency of vibration from about 120 Hz to 75 Hz is evident when using the MAG FS as well as the virtual elimination of a high frequency component of about 15kHz.

k. Clamping the end of the barrel does not appear to reduce the size of the MR any more than a sizeable mass would.

l. Rotating a FS does not alter MPI or MR.

m. Unscrewing a MAG FS outwards from the muzzle seems to reduce the size of MR even more than when installed fully home

n. The distribution of mass as governed by the design of the MAG FS does not appear to be a significant factor in reducing MR.

The recordings of muzzle movement suggest highly damped barrel motion. All F89 and Minimi barrels have two fixture points. The chamber end of these barrels are secured in place by a lever-type support latch. The other connection point is where the gas port regulator and the gun stock meet. Therefore any barrel vibration would have two nodes at these points. When additional support was given to the Minimi barrel's rear latch it had the effect of reducing bullet dispersion. It was also noted that adding weights to the muzzle end of the Minimi barrel altered the MPI. These discoveries together with the higher frequency components seen in the muzzle movement recordings suggest viscous losses resulting from fixtures that are non-rigid. Furthermore the test described for Table 5 where the muzzle of the barrel was pinned down (which allowed no displacement but could have possibly allowed rotation) suggests that some of the dispersion may be due to curvature during barrel vibration. This would indicate that measurement of the muzzle end position may not have been sufficient to characterise the effect of the barrel on launch dynamics. It is possible that the barrel tip may have been in a neutral position but moving with a high lateral

velocity at the time of projectile release ie muzzle tangent being more critical than x-y position.

It was also not possible to measure the effect on muzzle displacement by the torque imparted to the barrel from the spinning projectile. Barrel rotation may have defocussed the IR beam of the detector circuitry thereby giving an apparent deflection. It is also not entirely certain whether the stand used to support the muzzle motion detection equipment remained unaffected by vibration or muzzle blast. However, despite these limitations, the same barrel/flash suppresor combination appeared to produce repeatable muzzle movement patterns.

It would be difficult to say with the limited resources and time spent on the project exactly what the conditions were which so dramatically affect accuracy. The exit gasdynamics would also seem to be a factor in determining trajectory. Typically one could expect that the bow-shock flow and internal reflections within the MAG 58 FS would dominate aerodynamics. However, microflash photographs reveal strong evidence of significant blow-by with both MAG and Minimi FS. This suggests that the aerodynamics is dominated by the gas flow around and ahead of the projectile which could interact with the formation of the outer blast wave or the inner shock bottle (the supersonic flow region surrounding the muzzle during a projectile's launch - see figure 17) and this may have the effect of reducing the turbulent flow conditions around the projectile.

It is possible that results found with the thick walled single shot barrel may not have been representative because conditions would have been as near to ideal for accuracy and improvements would therefore have been minimal.

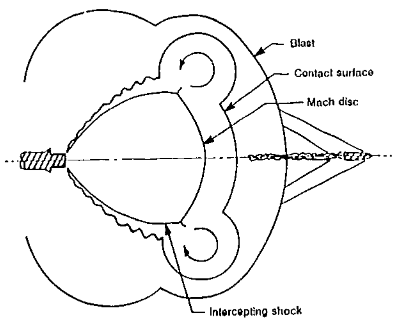

Figure 17: Schematic of muzzle flow

5. Conclusions and Recommendations

Numerous experiments were conducted on an F89 light machine gun to determine the effect of different flash suppressor designs on accuracy. It has been found that addition of a flash suppressor from a MAG 58 machine gun will reduce the size of mean radius dispersion by as much as 41% over a Minimi barrel fitted with its standard flash suppressor, and by 35% over a bare F89 barrel. It has been determined that the addition of a mass (with no flash suppressor devices fitted) to the end of a Minimi barrel will reduce dispersion size by up to 19% over the standard configuration but have no effect on dispersion when fitted to the end of an F89 barrel.

This evidence suggests that the the parallel sided F89 barrel is stiffer than the taper ended Minimi barrel and that a muzzle mass would reduce flexing in the Minimi barrel but have minimal effect in the F89 barrel. Testing reveals that some of the projectile dispersion may have been due to curvature during barrel vibration. Measurement of the muzzle end position may not have been sufficient to characterise the effect of the barrel on launch dynamics ie. it is possible that the barrel tip may have been in a neutral position but moving with a high lateral velocity at the time of projectile release.

The exit gasdynamics would also seem to have played a significant role in determining trajectory. Typically one could have expected that the bow-shock flow and internal reflections within the MAG 58 FS would have dominated aerodynamics. However, microflash photography revealed strong evidence of significant blow-by with both MAG and Minimi FS which suggests that the aerodynamics was dominated by the gas flow around and ahead of the projectile and that this may have had the effect of reducing the turbulent flow conditions around the projectile.

A detailed study of gun muzzle exhaust flow appears formidable and would need to include a detailed theoretical analysis on the processes of turbulence, two phase gas flow and chemical reactions. These requirements go well beyond the relatively simplistic experimental work performed here. The data obtained here can be used to assist with the formation of any theories on this subject. It is recommended that further work be performed to clarify the effect of barrel vibration and gasdynamic effects on accuracy.

6. Acknowledgements

The Author wishes to thank Messrs. Forbes, Teague and Almond of Gun Technology and Messrs. Roberts, Hanlon, Logan and Stott of EDE for their support during this task.

7. References

1. EDE SARP Report - Australian MINIMI F89 Light Support Weapon (LSW)/Flash Suppressor Test Report - 10 July 1989

Appendix 1

Optical Proximity Switch - Operating Principles

An infra-red optical switch which is normally used to detect changes . surface reflections was found to be highly suited to the detection of small changes in displacement. By determining its optimum forward current bias point it was possible to work within a linear part of the output voltage respose curve. Instead of simply detecting a change in contrast the system relies on the transmitter's tightly focussed beam (the optical head is designed to be used at a fixed distance from the reflective surface) and the defocussing created by moving the surface to be measured either to or away from the sensing head provides a corresponding change in the output voltage of the unit. Figure 18 shows the linear response of the output voltage possible with this system for a given change in distance while figure 19 shows a circuit diagram of the complete proximity detector.

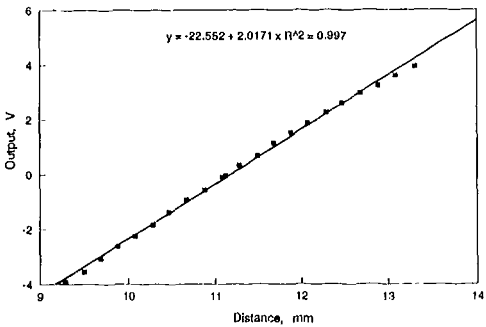

Figure 18: Linear output voltage response curve for changes in distance to the optical head

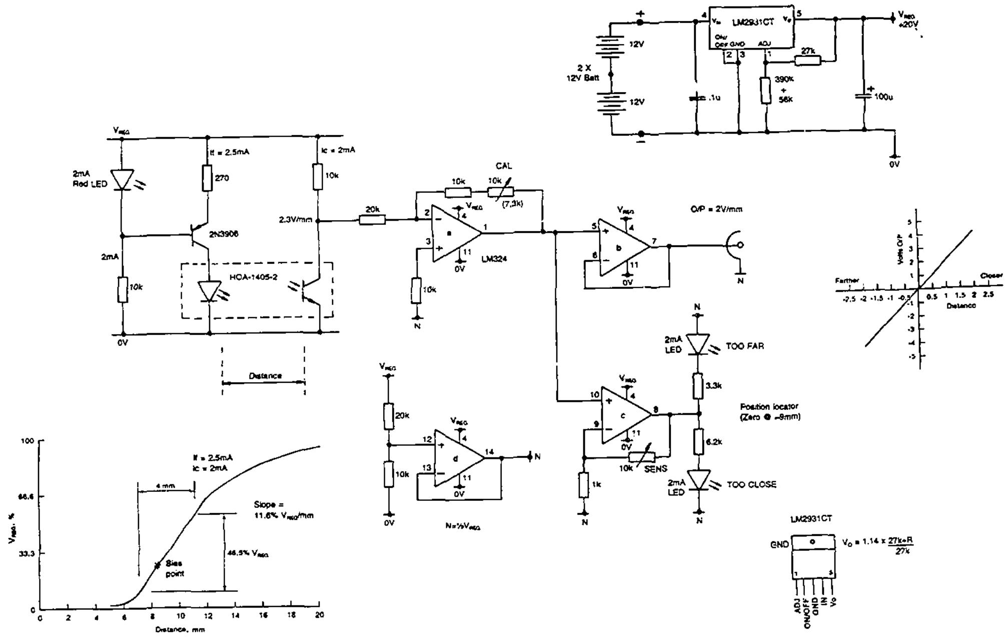

Figure 19: Proximity detector circuit diagram

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ABSTRACT

Tests were performed to determine the accuracy of an Australian F89 light machine gun having barrels fitted with or without flash suppressors. The results of these experiments are presented in this report. It was observed that the addition of a flash suppressor from a MAG 58 machine gun can reduce the size of mean radius dispersion by as much as 41% over an original Minimi flash suppressor and 35% over none being fitted. It appears that when using standard taper-ended Minimi barrels 19% of this improvement can be attributed directly to the mass of the MAG 58 flash suppressor but that this mass has no apparent effect on accuracy when using heavier F89 barrels.

It was concluded that gasdynamic effects due to flash suppressor design may have a significant role in weapon accuracy and merit further study.

Experiments to Determine the Effects of Different Flash Suppressor Designs on Accuracy of an F89 Light Machine Gun

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(DSTO-GD-0003)

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